REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 10, 1995	Final 1 Jun 91 - 31 Jul 95

4. TITLE AND SUBTITLE

A book and series of monographs on ice physics

5. FUNDING NUMBERS

DAAL03-91-G-0164

6. AUTHOR(S)

Victor F. Petrenko

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Thayer School of Engineering, Dartmouth College,
Hanover, NH 03755

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U. S. Army Research Office
P. O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARO 28599.4-GS

11. SUPPLEMENTARY NOTES

The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

SuperCedes AD-A 288319

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

During the period June 1, 1991, through May 31, 1995 seven monographs on the physics of ice were written and printed:

1. The Structure of Ordinary Ice. Part I: Ideal Structure of Ice.
2. Defects in Ice. Part I: Point defects.
3. Defects in Ice. Part II: Dislocations and Plane Defects.
4. Electrical properties of ice:
   Part I. Conductivity and Dielectric Permittivity of Ice.
   Part II. Advanced Topics and New Physical Phenomena.
5. The Surface of Ice.
6. Electromechanical Phenomena in Ice.
7. Optical Properties of Ice.

These monograph number 646 pages including 221 figures and 850 references. The lists of the monographs contents is in the Appendix. All the monographs of the series passed through intensive national and international review and were very well accepted by scientists and engineers working on ice. **Eighth monograph** entitled Photoelectric and Photoplastic Effects in Ice will be finished soon.

14. SUBJECT TERMS	15. NUMBER OF PAGES
ice, ice physics, electrical properties of ice, mechanical properties of ice, structure of ice, ice defects	6
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

A BOOK AND SERIES OF MONOGRAPHS ON ICE PHYSICS

FINAL REPORT

VICTOR F. PETRENKO

JULY 7, 1995

U. S. ARMY RESEARCH OFFICE

GRANT NUMBER DAALO3-91-G-0164

THAYER SCHOOL OF ENGINEERING
DARTMOUTH COLLEGE
HANOVER, NH 03755

STATEMENT OF THE PROBLEM

At present, many thousands of people around the world deal with ice, snow, and permafrost. They include basic and applied scientists, engineers, navigators, meteorologists and others. While just a small number of these people makes a contribution to basic Ice Physics, all of them use, more or less frequently, knowledge from it. Moreover, much successful applied research is based on fundamental science. This is just one reason for ice specialists to have an up-to-date textbook on Ice Physics on their desks.

Several times in the past this kind of book was produced. First it is necessary to mention Fletcher's book on "The Chemical Physics of Ice" [1]. Fletcher designed his book in a typical textbook format: it is reasonably brief and easy to understand. He touched on a few of the most important topics, but not all of them. The most complete and fundamental book of Ice Physics was written by Hobbs [2], in which he considered almost all aspects of the basic knowledge of ice known in 1972. Another work was subsequently written by John Glen in 1974 [3]. He wrote briefly and clearly and reviewed almost all subjects. This work (two monographs) was (and in some respects still is) a magnificent introduction to ice. Finally, Maeno wrote (in Japanese) a simple popular book [4] the purpose of which was to attract people's attention to the subject.

All of these are now out of date. During the past twenty years a significant amount of new experimental and theoretical work has appeared, to the extent that our views on Ice Physics have dramatically changed. New areas of research have opened up based upon recent discoveries. Intensive studies in physics, chemistry and the mechanics of ice have resulted in the formulation of physical laws using simpler and more direct ways; we have discovered that some of the physical models previously used were incorrect. So, we may now say that the Physics of Ice is a much better understood subject than it was twenty years ago. A list of particular achievements and discoveries in ice research was included in the first proposal.

These reasons explain the need for a new book on ice physics. The Principal Investigator was given a contract from ARO and US Army CRREL to produce such a book and began this work in June 1991.

SUMMARY OF THE MOST IMPORTANT RESULTS

During the period June 1, 1991, through May 31, 1995 seven monographs on the physics of ice were written and printed:

1. The Structure of Ordinary Ice. Part I: Ideal Structure of Ice.
2. Defects in Ice. Part I: Point defects.
3. Defects in Ice. Part II: Dislocations and Plane Defects.
4. Electrical properties of ice:
   Part I. Conductivity and Dielectric Permittivity of Ice.
   Part II. Advanced Topics and New Physical Phenomena.
5. The Surface of Ice.
6. Electromechanical Phenomena in Ice.
7. Optical Properties of Ice.

These monograph number 646 pages including 221 figures and 850 references. The lists of the monographs contents is in the Appendix. All the monographs of the series passed through intensive national and international review and were very well accepted by scientists and engineers working on ice. **Eighth monograph** entitled Photoelectric and Photoplastic Effects in Ice will be finished soon.

P. I. was simultaneously working on the united book on Ice Physics. This work is mostly accomplished and proposals were sent to four publishing houses : Oxford University Press, Cambridge University Press, Taylor & Francis and IOP. Oxford University Press and Taylor & Francis have finish the proposal evaluation are ready to sing a contract. Cambridge University Press and IOP will reply by October 1.

Below are the contents of these eight monograph:

1. THE STRUCTURE OF ORDINARY ICE Ih. PART I : IDEAL STRUCTURE OF ICE

2. DEFECTS IN ICE. PART I. POINT DEFECTS

3. DEFECTS IN ICE. PART II. DISLOCATIONS AND PLANE DEFECTS

4. ELECTRICAL PROPERTIES OF ICE

ELECTRICAL PROPERTIES OF ICE, PART II

ADVANCED TOPICS AND NEW PHYSICAL PHENOMENA

5. ICE SURFACE

6. ELECTROMECHANICAL PHENOMENA IN ICE

FIGURE CAPTIONS
FIGURES

7. OPTICAL PROPERTIES OF ICE
PREFACE
INTRODUCTION
NOMENCLATURE
DEFINITIONS
DIELECTRIC PERMITTIVITY OF ICE FROM SONIC TO X-RAY FREQUENCY
ANISOTROPY AND BIREFRINGENCE OF ICE IH
ABSORPTION AND REFLECTION OF ULTRAVIOLET LIGHT
ABSORPTION AND REFLECTION OF INFRARED LIGHT.
RAYLEIGH SCATTERING OF ICE
RAMAN SCATTERING
PHOTOLUMINESCENCE
LUMINESCENCE UNDER ACTION OF HIGH ENERGY PARTICLES
THERMOLUMINESCENCE
TRIBOLUMINESCENCE
BIBLIOGRAPHY
FIGURE CAPTIONS
FIGURES

These monograph number 646 pages including 221 figures and 850 references. The lists of the monographs contents is in the Appendix. All the monographs of the series passed through intensive national and international review and were very well accepted by scientists and engineers working on ice. Eighth monograph entitled Photoelectric and Photoplastic Effects in Ice will be finished soon.

8. PHOTOELECTRIC AND PHOTOPLASTIC EFFECTS IN ICE

PREFACE
INTRODUCTION
NOMENCLATURE
INTRINSIC PHOTOCONDUCTIVITY OF ICE
IMPURITY PHOTOCONDUCTIVITY OF ICE
LIFE TIME OF NONEQUILIBRIUM CHARGE CARRIERS IN ICE
NATURE OF PHOTO-CHARGE CARRIERS IN ICE
ELECTROMOTIVE FORCE
ELECTRO-OPTICAL EFFECTS AT ICE-SEMICONDUCTOR INTERFACES
POSSIBILITY OF ICE SOLAR CELLS
PHOTOPLASTIC EFFECT IN ICE
BIBLIOGRAPHY
FIGURE CAPTIONS
FIGURES

LIST OF PUBLICATIONS

1. V. F. Petrenko "Electrical Properties of Ice", Monograph, *USA CRREL Special Report 1993-20.* 1993.
2. V.F.Petrenko "Structure of Ice. Part I: Ideal Structure of Ice" Monograph, *USA CRREL Special Report 1993-25.* 1993.
3. V.F.Petrenko and R. W. Whitworth. "Defects in Ice. Part I. Point Defects." *USA CRREL Special Report 1994-4*, 1994.

4. V.F.Petrenko and R. W. Whitworth."Defects in Ice. Part II. Dislocations and Plane Defects." *USA CRREL Special Report 1994-12,* 1994.
5. V. F. Petrenko." The Surface of Ice". *USA CRREL Special Report 1994-22*, 1994.
6. V. F. Petrenko." Electromechanical Phenomena in Ice ". *USA CRREL Special Report* 1995-##, in press.
7. V. F. Petrenko." Optical Properties of Ice". *USA CRREL Special Report* 1995-##, in press.

REFERENCES

1. Fletcher, N. M. (1970) "The Chemical Physics of Ice," 271p., Cambridge University Press
2. Hobbs, P. V. (1974) "Ice Physics," 837p., Clarendon Press, Oxford
3. Glen, J. W. (1974) "The Physics of Ice," 80p., CRREL monograph
4. Maeno, N. (1981) "Science on Ice," Hokkaido University Press, (in Japanese)